WASHINGTON STATE
DEPARTMENT OF TRANSPORTATION

IN-DEPTH CATHODIC PROTECTION SYSTEM INSPECTION AND RECOMMENDATIONS

MAY 2006

LACEY V. MURROW BRIDGE (90/25S)
HOMER HADLEY BRIDGE (90/25N)

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EXECUTIVE SUMMARY

Two floating structures, the Homer Hadley Bridge (Bridge No. 90/25N) and the Lacey V. Murrow Bridge (Bridge No. 90/25S) carry Interstate I-90 between Seattle and Mercer Island. The Homer Hadley Bridge was completed in 1989 and is comprised of 18 floating concrete pontoons. The Lacey V. Murrow Bridge was completed in 1993 and is comprised of 20 floating concrete pontoons. Steel cables anchor the pontoons in place. An impressed current cathodic protection system is installed on each cable to prevent corrosion and increase its service life.

An in-depth inspection of all cathodic protection systems and adjustments to the system were conducted from March 6 to March 25, 2006. This report documents the findings of the inspections and provides recommendations for effective implementation of cathodic protection technology.

A visual inspection of all components of the Cathodic Protection System was conducted. Each anode assembly was pulled out and visually observed. Standard system operating parameters were measured and depolarization and polarization testing were performed.

Visual survey of all anodes of the Homer Hadley Bridge indicated that 46% of the original Platinum anodes have failed to date due to deficient endcaps, kinking of the wires, and localized high current densities. A total of 20 new titanium anodes have been installed based on the recommendations provided after the 2004 Inspection the system. At present 4 zones (8%) do not have anodes and are not operational. Rectifiers are also exhibiting signs of aging and need maintenance.

The condition of the newer Lacey V. Murrow Bridge cathodic protection system was somewhat better. The failure frequency of the PT anodes in this bridge is 11%. A total of 6 new titanium anodes have been installed and all zones are operational. Two rectifiers were replaced during inspection due to malfunctioning components. The system on the LVM Bridge is much newer than the Homer Hadley Bridge, and therefore, exhibits lesser degree of wear and tear.

The new anode design, recommended after the 2004 inspection, resulted in very high resistance. Therefore, a maximum of only 1 ampere can be output by these anodes. This limitation can be overcome by increasing the length of the anodes. A new anode design is provided in this report and will need to be implemented. This design is based on testing performed at site with various lengths of anodes and mathematically modeling the resistance.

The results of this inspection and the earlier underwater inspection suggest that a more aggressive maintenance and monitoring program is required. Replacement of the missing or damaged anodes should be a high priority and be competed within the next 12 months. If additional rectifiers fail, and a few can be expected to, they should be replaced as soon as possible. A system monitoring and control plan is not in place and it is recommended that one be developed and implemented within the next year. This would provide the necessary guidance to the maintenance crew. At present the maintenance crew has no guidelines to operate and maintain the system. The platinum-niobium anode is not particularly suited for this application; an upgrade to the titanium based anode in the next 5 years is recommended. The rectifiers are aging and will need replacement in the next 5 to 10 years. They should be replaced with ones that can be remotely controlled and monitored. This would allow a more efficient mechanism to monitor and maintain the system.

DESCRIPTION OF THE CATHODIC PROTECTION SYSTEM

Two floating structures, the Homer Hadley Bridge (Bridge No. 90/25N) and the Lacey V. Murrow Bridge (Bridge No. 90/25S) carry Interstate I-90 between Seattle and Mercer Island. The Homer Hadley (HH) Bridge is the larger of the two structures and is located north of Lacey V. Murrow (LVM) Bridge. The HH Bridge carries three lanes of westbound traffic towards Seattle and two reversible express lanes which carry traffic in either direction depending on the time of the day. The LVM Bridge carries three lanes of eastbound traffic towards Mercer Island.

The HH Bridge was completed in 1989 and is comprised of 18 floating concrete pontoons designated as Pontoon A at the Seattle end of the bridge to Pontoon R located at the Mercer Island end. The Pontoons are anchored to the lake floor with steel cables which maintain the alignment of the structure. The end pontoons, A and R, are aligned in the north-south direction and are anchored with four cables each, two on the north end and two on the south end of the pontoons. Pontoons B to Q are aligned in the east-west direction and are anchored in place by two perpendicular cables located at the center of the pontoon, one on the north side and one on the south side, except Pontoon J. In addition to having the north and the south cables, Pontoon J has 12 longitudinal cables, six of which are located on the north side and six on the south side. The layout of the pontoons and the cables is presented in Figure A-1 in Appendix A.

The LVM Bridge was completed in 1993 and is comprised of 20 floating concrete pontoons designated as Pontoons A to T from Seattle to Mercer Island (west to east). The makeup of LVM bridge is very similar to the HH with Pontoons A and T aligned in the north-south directions anchored with four cables each and the rest of the pontoons aligned in the east-west direction anchored in place by two cables with the exception of Pontoon F and G. Pontoon F has 8 longitudinal cables and Pontoon G has 4 longitudinal cables.

The cable assembly on each pontoon is comprised of the anchor, the steel cable, and the tensioning assembly. The entire length of the cables is submerged in water and protected by an impressed current cathodic protection system. Each cable is protected by an independent cathodic protection zone comprising of a rectifier and either a platinum-niobium anode or a mixed-metal oxide titanium anode. The platinum-niobium (PT) anode assembly is comprised of an insulated copper wire to supply the impressed current, the anode, the termination cap, a weight, and a rope attached to the weight to lower the anode assembly in the water. The anodes are either Anomet 20 or Anomet 40 with a diameter of 0.125 inches. The connection between the copper wire and the anode is made in the endcap. The anode assemblies are submerged in water adjacent to the cable to be protected and the length of the PT anode varies from one system to another. The anode assemblies are positioned such that the top of the anode wire is approximately 15 to 20 feet below the bottom of the pontoon.

The mixed-metal oxide titanium (titanium) anodes were installed as replacements to the PT anodes based on recommendations provided by this team after the 2004 inspection of the cathodic protection systems. The titanium anodes were selected as they offered a service life in excess of 20 years. In addition, the length of the titanium anodes required to provide equivalent current compared to the PT anodes would be significantly lower. The shorter length of 3 feet 3 inches (1 meter) is much more convenient to handle compared to the 30 to 80 feet length of the PT anodes. The much smaller diameter (0.125 inches) and the longer length of the PT anodes made them susceptible to kinks and damage. The titanium anodes are more robust and approximately 1 inch in diameter. In addition, the connection between the copper wire and the titanium anode is made using a special process that results in a connection which is much more robust that that used in the PT anodes. These connections are not considered to be prone to the kind of failures experienced by the PT anode endcaps. This anode assembly is comprised of a copper wire to supply the impressed current, the anode, and a weight to hold the anode down. The titanium anodes are positioned a few feet below the bottom of the pontoons. The titanium anode is 1 m in length and has three crimp points. The insulated copper wire passes through the hollow section of the anode. The crimps at the top and the bottom of the anode provide a watertight seal and the crimp in the middle provides an electrical connection to between the copper wire and the titanium anode. At each crimp point a copper sleeve is installed. The copper sleeve is required for the crimping process and is designed to corrode with the application of cathodic protection current and is expected to dissolve away. Figure A-2 in Appendix A presents various photographs of the titanium anodes. These photographs show the anode, the copper sleeve corroding upon application of current, and the anode after the copper sleeve has completely dissolved.

The rectifiers are located inside the pontoons, close to the subject cables tensioning assembly. There are two different makes of rectifiers. The majority of the rectifiers are manufactured by Universal Rectifiers and a few are manufactured by Goodall Rectifiers. The rectifying element in the rectifiers is silicon stack and the output of the rectifiers is not filtered. The output of all rectifiers is rated at 80 Volts and 5 amps. The shunts installed in the rectifiers are rated for either 50 mV/5 Amps or 50 mV/10 Amps. The rectifiers are housed in a steel enclosure mounted on a wall near the cable tensioning unit. Each rectifier is completely independent of the others and is powered by 115 V AC available in each pontoon. Visual inspection of the steel enclosures suggests that they may be in compliance with NEMA-3 requirements.

There are a total of 52 impressed current cathodic protection zones on the HH Bridge and 56 zones on the LVM Bridge. A total of 108 rectifiers are powering 116 anodes.

TESTING PERFORMED

An in-depth inspection and adjustment of the impressed current cathodic protection system was performed between March 6 and March 25, 2006 by CONCORR, Inc. and Hardesty and Hanover personnel. The CONCORR, Inc. team was lead by Ali Akbar Sohanghpurwala a NACE certified Corrosion and Cathodic Protection Specialist and Hardesty and Hanover was represented by Frank Altro, P.E.

Mr. Tim Benson, Movable Bridge Electrical Engineer from the Bridge Preservation office of the Washington State Department of Transportation in Olympia was present throughout the inspection to assist, observe, and schedule crew and equipment for the inspection. He also provided relevant information pertaining to the maintenance and operation of the systems. Washington State Department of Transportation bridge maintenance personnel located on site assisted in the inspections by providing a boat and vehicles to access the required locations, access to the anodes and the rectifiers, and assisted in the inspection.

VISUAL SURVEY

A visual survey of the rectifiers and the anodes was conducted. Each anode cable was retrieved from the lake and its condition was visually observed and documented. During the visual survey, at some locations where the platinum anode had failed, new titanium anodes were installed by the Washington State Department of Transportation maintenance crew. The inspection team assisted when appropriate with the installation.

SYSTEM OPERATION PARAMETERS

All system operation parameters were measured for each impressed current cathodic protection system and included, true root mean square (TRMS) system current, TRMS system voltage, and anode and cable "instant-off" potentials. The accuracy of the rectifier panel instruments was verified.

The system current and voltage were read from the rectifier panel meters. These measurements were verified by measuring system current as a voltage drop across the shunt provided in each rectifier and measuring the system voltage across the output terminals.

The anode and cable potentials were measured using a portable silver-silver chloride reference cell designed for use in a marine environment. The reference cell was submerged in the water and it was connected to the negative terminal of the multimeter. The positive terminal of the multimeter was connected to either the positive (i.e. anode) or the negative (i.e. cable) terminal of the rectifier (see Figure A-3 in Appendix A). The "instant-off" potential was measured when the rectifier current output went to zero. As the rectifier output is not filtered, the "off" potential of the anode and anchor cables can be obtained by measuring the minimum and maximum peak of the waveform, respectively. The peaks of the waveforms can be measured by using the min-max function of the multimeter. However, presence of noise makes it difficult to obtain accurate peak measurements. Therefore, the instant-off potentials were measured by manually powering down the rectifier for 1 second.

One of the challenges that had to be overcome during the inspection was to submerge the reference cell in the water and simultaneously connect to the cable or the anode wire in the rectifier. On the LVM Bridge, this was accomplished by dropping the reference cell in the water adjacent to the access hatch located on the north side and routing the reference cell cable to the rectifier through the hatch. On the HH Bridge the reference cell was routed through the north cable port in each pontoon to the outside and then dropped in water. This process was developed during the last inspection and the access points created were left in place for use in future. It should be noted that placing the reference cell in this fashion makes it susceptible to picking up interference from adjacent systems and it measures an average of all the elements present in the vicinity of the reference cell. In ideal conditions, the reference cell would be placed very close to the cable or the anode whose potential is to be measured.

Depolarization/Polarization Testing

After system operation parameters were documented the instant-off potentials of the anode and the steel cables were measured, all rectifiers were powered down and the systems were allowed to depolarize for 4 to 7 days. The static potentials of the anodes and the cables and anode to cable resistance were then measured. After static and resistance measurements were completed on all zones, all rectifiers were powered up. After allowing the system to stabilize for 3 to 7 days, the rectifier operating parameters and instant-off potentials were measured.

Adjustment of System Output Current

After the systems were reenergized, the output currents of the rectifiers were adjusted to bring uniformity to the system. Prior to the adjustment the output current of the rectifiers varied from 0.22 to 5.69 Amps. The primary goal of this adjustment was to simplify the management of the systems and provide uniform cathodic protection to the cables. In the present condition, some cables were overprotected and others were under-protected.

Based on data obtained during the evaluation, the following target current settings were estimated:

HH Bridge North Cables: 2.5 Amps

HH Bridge South Cables: 2.5 Amps

LVM Bridge North Cables: 1.0 Amp

LVM Bridge South Cables: 1.5 Amps

These current settings were based on average current output in the as is condition and the instant-off potentials of the cables. These current outputs will need to be further refined with time. The tap settings on each rectifier were adjusted to provide a current as close to the desired value as possible. In some zones, the above guidelines were not followed and a different current was set to compensate for missing anodes, etc. In zones, which contained the new titanium anodes the output current could not be set to more than 1 Amp as the resistances of the new anodes to the cables was in the range of 90 to 100 ohms. At these resistances, the output voltage required to output more than 1 Amp exceeded the rated maximum output voltage of the existing rectifiers.

TEST FINDINGS

VISUAL SURVEY

All cathodic protection components, especially the anodes were visually inspected. Each and every anode was pulled out of the water and visually inspected. Photographic documentation of typical deterioration was made. These are presented Figure A-4 in Appendix A.

Homer Hadley Bridge

There are a total of 52 rectifiers and 52 anodes installed on this bridge. At the end of the last evaluation in 2004, 15 of the 52 zones were not operational due to missing anodes. The remaining anodes had exhibited signs of accelerated consumption of platinum at the top of the anode and in some cases at the bottom of the anode. The condition of many of the endcaps was not satisfactory. Some had started to deteriorate and water was penetrating inside the caps. In some endcaps the mechanical crimp were extending outside the endcap and water was able to easily penetrate inside it. In general, the quality of the endcaps was considered to be poor considering the environment it is to be used in. Water penetration inside the caps can result in failure of the connection due to corrosion of the copper in the crimps. During this evaluation the condition of the endcaps was similar to the previous evaluation. In fact several more anodes failed since the last inspection due to failure in the endcaps.

Prior to the start of this inspection, the maintenance group had purchased a total of 26 new titanium anodes of the type recommended in the last evaluation report. Since the last evaluation 6 more anodes failed and 3 additional anodes failed during visual condition evaluation. This resulted in a total of 24 zones requiring new anodes. Of the 24 zones, new anodes have been installed in a total of 20 zones and 4 more zones require new anodes. At the end of this evaluation, 48 (compared to 37 zones during the last evaluation) zones are functional. The remaining 28 platinum anodes exhibit varying degrees of deterioration and more of them can be expected to fail in the near future.

Some rectifiers exhibited signs of aging. Ground and anode wire exhibited wear and tear at the lug connections. A few switches for controlling the installed meters were malfunctioning and need replacement. Sparking in the silicon stack and deterioration of paint on the silicon stacks was observed in some rectifiers (see Figure A-5 in Appendix A). Foul smell emanated from silicon stacks in some of the rectifiers when the rectifiers were reenergized. The foul smell always accompanied sparking in the silicon stacks. In some silicon stacks dead insects were observed between stacks of silicon. It was thought that the foul smell was generated by electrocution of dead insects. However, this was not conclusively verified.

The detailed results of the visual survey are presented in the Appendix. A data sheet for each zone is presented and all data pertaining to that zone, including data collected during the 2004 evaluation are also presented.

Lacey V. Murrow

There are a total of 56 rectifiers and 64 anodes. Several zones have two anodes instead of one. At the end of the 2004 inspection, a total of 5 the rectifiers were powered down due to failed anodes. Four new titanium anodes had been installed prior to the inspection. One of the new anodes was installed on Zone A2-N. This zone has two anodes and after one had failed the system was operating on one anode. At the start of this evaluation only two rectifiers were off. In addition to the two zones that are off and need a new anode, Zone T1-N also needs a new anode. Zone T1-N was designed to have two platinum anodes and one of them has failed.

The general condition of the platinum anodes is better than the HH Bridge. One anode was kinked during evaluation and is expected to fail in the near future.

Rectifiers exhibited normal wear and tear. Failed switches, missing bolts that hold the rectifier frame onto the NEMA 3 enclosure, stuck enclosure doors, meters experiencing loss of calibration, faulty breaker, etc. were observed. Silicon stack of one Goodall rectifier failed upon reenergizing and the rectifier was replaced by a spare Universal Rectifier and on another rectifier the breaker was malfunction and the rectifier was replaced. On some rectifier silicon stacks, the paint was peeling off and exhibited signs of deterioration. Sparks were noted on silicon stacks of some rectifiers when they were energized and the sparking was accompanied by a foul smell.

The detailed results of the visual survey are presented in the Appendix. A data sheet for each zone is presented and all data pertaining to that zone, including data collected during the 2004 evaluation are also presented.

DEPOLARIZATION/POLARIZATION TESTING

Many practitioners use polarization (i.e. change in its potential resulting from cathodic protection) of the protected element, the cables for determining the adequacy of the cathodic protection system. The shift in potential is dependent on many variables including the environment. A shift of 0.300 V is considered to be adequate for most environments. In fresh water the -0.800 V criterion is considered to be more relevant and a more stringent criterion. This criterion requires that the polarized potential of the cable be lower than -0.800 V with respect to silver-silver chloride reference cell.

To apply either of the above criteria, one needs to accurately measure the instant-off potential of the cable. In the present setup, accurate measurement of the instant-off potential is not possible due to interference from the neighboring zones. To accurately measure the instant-off potentials, all rectifiers on both bridges will need to be simultaneously powered off each time an instant-off measurement on the cable is made. Instant-off measurements during this inspection and the previous inspection were made with only one rectifier, the one associated with the cable whose instant-off potential was to be measured, powered down during measurement. When the associated rectifier was powered down, some current from neighboring rectifiers was received by the cable under measurement, and therefore, the measured potential included an erroneous potential drop due to current flow. The static potentials measured are also not accurate as they are the average of the adjacent cables. The primary operational goal of the system would be maintain the average instant-off potential of the cables slightly more negative than -0.800 volts with respect to silver-silver chloride reference electrode and at the same time make sure that no individual cable is more positive than -0.800 volts.

Therefore, the polarization/depolarization data is primarily used to identify problems in the system rather than for defining operating criteria.

Homer Hadley Bridge

The depolarization for HH Bridge varied from 64 to 4,300 mV with an average of 1,439 mV. As the component of IR drop in each measurement is not know, these depolarizations are not considered to be representative of true depolarizations. However, lower depolarizations on some of the cables is of concern, as with the subtraction of the IR drop the true depolarization in those zones would be lower that what is reflected here. The average static potential of the cables of the HH Bridge was -464 mV.

After adjustments of the output current, the average polarization was 879 mV and varied from 36 to 3,384 mV. All depolarization/polarization data is presented in Table 1 in Appendix B.

Lacey V. Murrow

The depolarization for the LVM Bridge varied from 92 to 905 mV with an average of 425 mV and the polarization varied from 39 to 947 mV with an average of 390 mV. The average instant-off potential after re-energization was -1,042 mV and the average static potential was -669 mV. All depolarization/polarization data is presented in Table 2 in Appendix B.

ANODE DESIGN BASED ON ANODE TO CABLE RESISTANCE

The anode to cable resistance controls the voltage required to power the system. The resistance between the anode and the cable needs to be maintained at levels such that the output voltage required at the desired current does not exceed the rectifier rated voltage. In addition, each anode type is capable of operating in a certain voltage range. As the anode to cable resistance of the titanium anodes came out to be significantly higher, an evaluation of the anode to cable resistances was conducted. The evaluation included, measuring resistance of all anodes to cable and various lengths of titanium anode to cable. The field analysis was supplemented with mathematical modeling of the resistance.

Generally, the geometry of the application does not lend itself to linear mathematical analysis. Therefore, it was assumed that the anode can be modeled as a cylindrical object submerged in a conductive medium. Its resistance to an object at infinity was calculated with established formulas. This was performed for both the PT and the titanium anodes. A good correlation was obtained between the resistance data collected in the field and that predicted by mathematical modeling. This assumption was reasonable as, all cables are grounded and therefore the resistance between the anode and the cable is the resistance between the anode and earth.

The results of the evaluation indicated that to reduce the anode to cable resistance below 40 ohms would require a titanium anode size of 3 meters. A resistance of 40 ohms would allow a current output just above 2 Amps, which would suffice for the operation of the system. However, an anode of 4 m length would increase the current output capacity to about 2.5 Amps and provide a margin of safety. Based on the polarization data obtained it is expected that the current requirement in the future will be reduced and therefore, 3 meter anodes are recommended for the structure.

The resistance data collected from all the platinum anodes suggests that during construction if the length of the PT anode installed did not produce the desired resistance, a second anode was installed adjacent to the first anode. In several zones of LVM Bridge, two anodes are installed instead of one. When a new titanium anode of appropriate length is installed in these zones, it is not necessary to install replacements for both the PT anodes. One of the PT anodes should be removed. It is not considered prudent to have a PT and a titanium anode in the same circuit. Due to the much higher resistance of the titanium anode, the majority of the current will flow out of the PT anode and accelerate its consumption.

Titanium anodes are available from two different manufacturers. The Eltech anodes previously purchased come only in 1 meter lengths. However, several 1 meter anodes can be chained together to obtain the length required. Another manufacturer, USFilter can manufacture the same anodes of varying length up to a limit. The higher resistivity of titanium limits the length of the anode. Therefore, alternating copper with titanium reduces the overall resistance. As the maintenance crew is familiar with the Eltech anodes, it is recommended that we continue to use these anodes in the future.

There are two ways to add additional 1 meter anodes; a) purchase 1 meter anodes separately and splice the anode cables outside the pontoons and encapsulate the splice with a waterproof splice kit or b) purchase 1 meter anodes in a string arrangement. In the string arrangement, 1 meter anodes are chained together using the anode cable. To implement the Option B, some of the strings anodes will need to have 2, 1 meter anodes and some 3, 1 meter anodes in a chain. The second option is recommended so that the number of splices required is reduced, thereby reducing failure points in the system.

As in many zones a 1 meter titanium anode has been installed, Tables 3 and 4 in Appendix B provides guidelines as to what should be done to each zone.

CABLE DESIGNATIONS

The labels on the south side of the LVM Bridge pontoons F and G incorrectly identify the longitudinal anchor cables. There were no labels at all on the north side of this bridge. Labels are also missing on the north side of pontoons A and R of the HH Bridge. It is recommended that missing labels be provided and the labels on the south side of pontoons FL4-S, FL5-S, and GL3-S of LVM Bridge be corrected. The correct labeling should also be installed on the rectifiers FL4-N, FL4-S, FL5-N, FL5-S, G-N, G-S, GL3-N, and GL3-S of LVM Bridge and the old labels be removed so as to not cause any confusion. The labeling on rectifiers of F-N and F-S should also be corrected.

CONCLUSIONS

HOMER HADLEY

In general the overall health of the system has improved since the last inspection. However, it is not what it should be. The platinum anodes in the remaining 28 zones are expected to fail in the next couple of years and should be replaced by the newer titanium anodes. This will significantly lower the maintenance required and allow all of the zones to be functional. In addition a replacement of the rectifiers should be planned in the next 5 to 10 years. The newer rectifiers should be remotely controlled and have the ability to allow remote monitoring.

LACEY V. MURROW

The health of the cathodic protection system and the anodes is much better than the HH Bridge. However, the platinum anodes with time are expected to fail as they have done in the HH Bridge and the rectifiers will also need replacement.

RECOMMENDATIONS

The recommendations are subdivided into maintenance and rehabilitation requirements.

MAINTENANCE

It is recommended that the following actions be taken:

1. Replace all missing and damaged anodes per Tables 3 and 4 of Appendix B within the next 12 months with alternate titanium anode design provided in Appendix E.

2. Correct labeling of anchors FL4-S, FL5-S, and GL3-S of LVM Bridge on the side of the pontoons. Provide missing labels on the north side of the LVM Bridge and pontoons A and R of HH Bridge.

3. Correct labeling of rectifiers of zones FL4-N, FL4-S, FL5-N, FL5-S, F-N, F-S, G-N, G-S, GL3-N, and GL3-S of LVM Bridge

4. Repair broken meter switches on rectifiers of zones H-S and J-N of HH Bridge and zones K-S and P-S of the LVM Bridge.

BRIDGE PRESERVATION OFFICE FOLLOW UP

1. Perform a follow up inspection within 2 years to ascertain if all cables are adequately protected.

2. Develop a system monitoring and control plan to insure that the system is run optimally.

REHABILITATION

1. Upgrade all anodes to titanium anodes in the next 5 years.

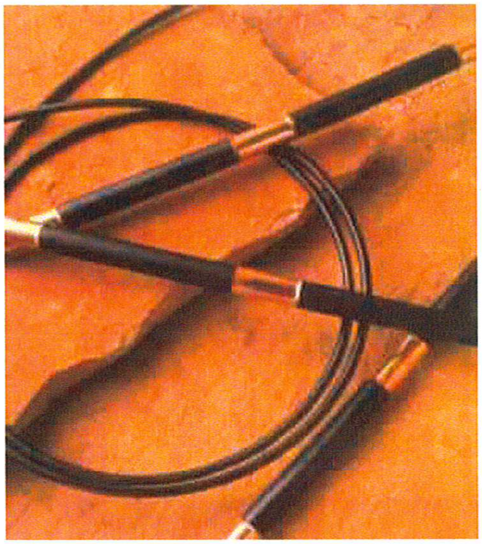
2. Upgrade the rectifiers to newer remotely controlled ones. This would allow a more accurate measurement of the instant-off potentials and more efficient operation of the system and reduce monitoring costs.

CONSTRUCTION COST ESTIMATES FOR REHABILITATION RECOMMENDATIONS

Description	Unit	Unit Cost	# of Units per Cable	Total Cost			
				Homer Hadley Bridge		Lacey V. Murrow	
				# of Cables	Total Cost	# of Cables	Total Cost
Materials							
2 Anode String	each	$ 600	1	17	$ 10,200	4	$ 2,400
3 Anode String	each	$ 900	1	35	$ 31,500	52	$ 46,800
Splicing Kit	each	$ 35	1	52	$ 1,820	56	$ 1,960
Rectifier	each	$ 1,500	1	52	$ 78,000	56	$ 84,000
Total Material Cost					**$ 121,520**		**$ 135,160**
Labor							
2 Anode String	man-hrs	$ 60	3	17	$ 3,060	4	$ 720
3 Anode String	man-hrs	$ 60	3	35	$ 6,300	52	$ 9,360
Splicing Kit	man-hrs	$ 60	1.5	52	$ 4,680	56	$ 5,040
Rectifier	man-hrs	$ 60	4	52	$ 12,480	56	$ 13,440
Total Labor Cost					**$ 26,520**		**$ 28,560**
Mobilization/Demobilization Cost					**$ 5,000**		**$ 5,000**
Contingency on Materials and Labor							
Materials (15%)					$ 18,228		$ 20,274
Labor (15%)					$ 4,728		$ 5,034
Total Contingency					**$ 22,956**		**$ 25,308**
Total Cost					**$ 175,996**		**$ 194,028**
Total Cost							**$ 370,024**

APPENDIX A

Figure A-2: Titanium Anode

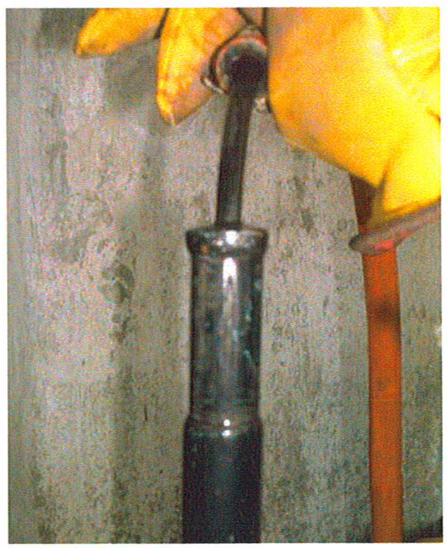


New Titanium Anode

Copper Sleeve Corrosion

Close up of Copper Sleeve Corrosion

Partially Corroded Sleeve



Completely Corroded Sleeve

Figure A-3: Potential Measurement Setup

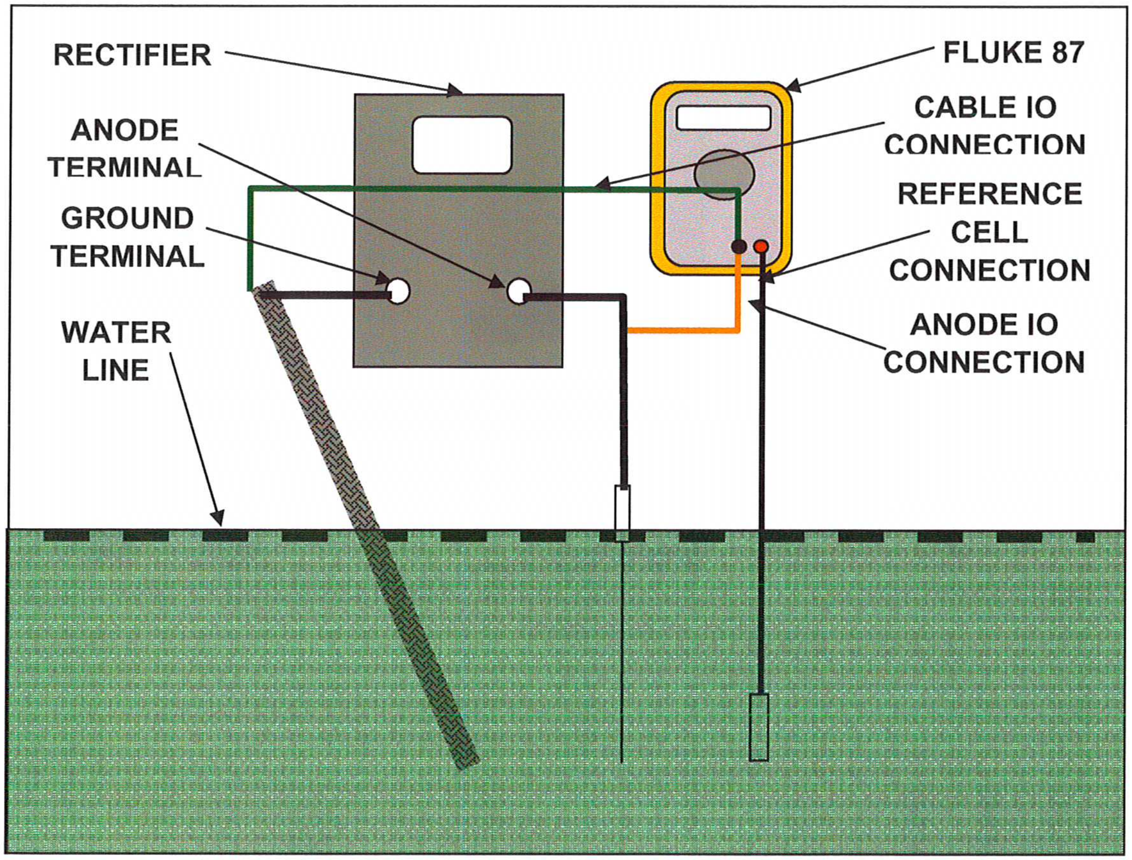
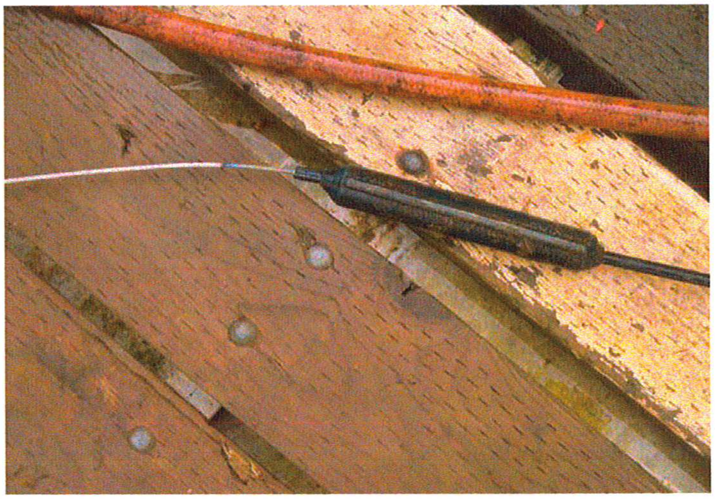


Figure A-4: Typical Damage on PT Anodes

PT Anode Broken at the Endcap.

Burn Mark on PT Anode just below the Endcap.



PT anode broken due to kink in the wire.

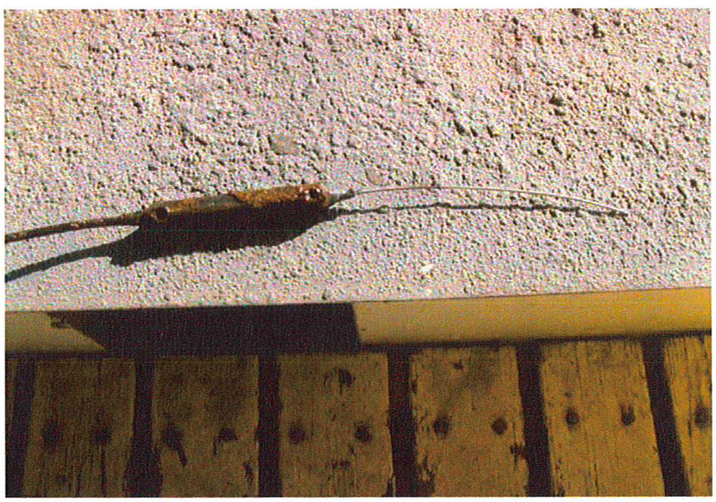
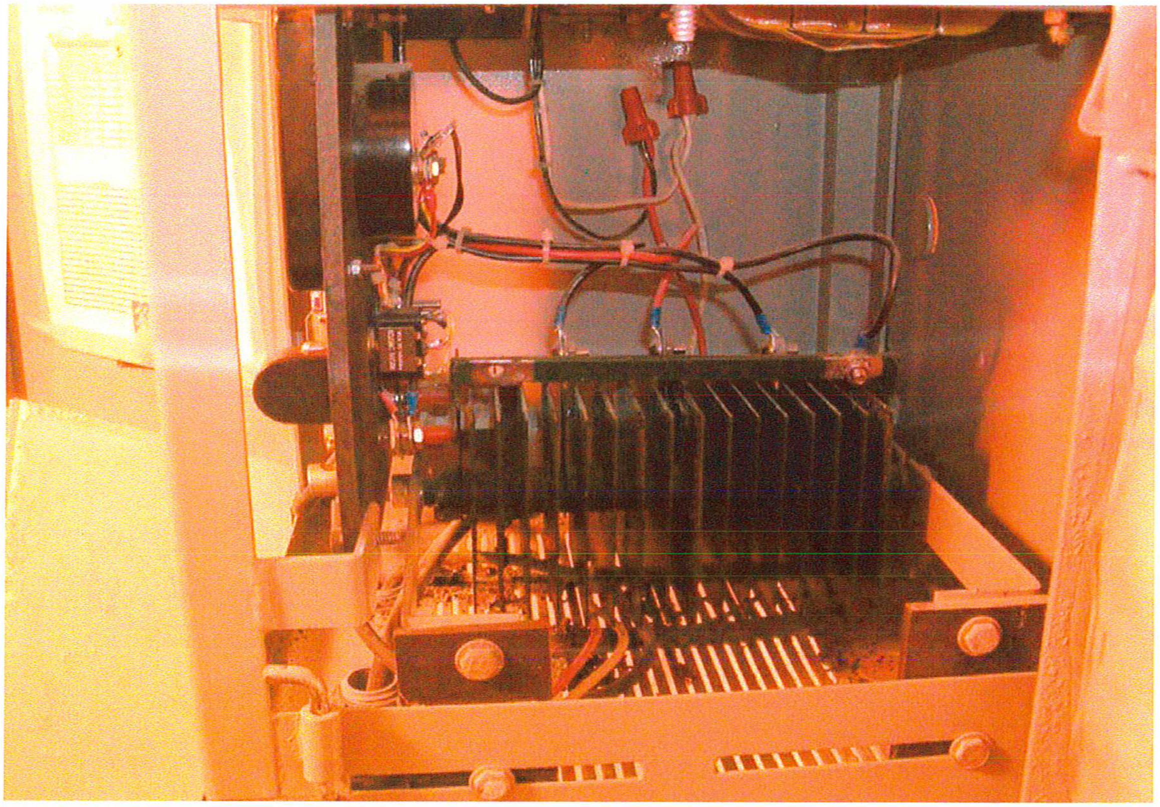


Figure A-5: Typical Silicon Stack



Silicon Stack exhibiting coating deterioration.

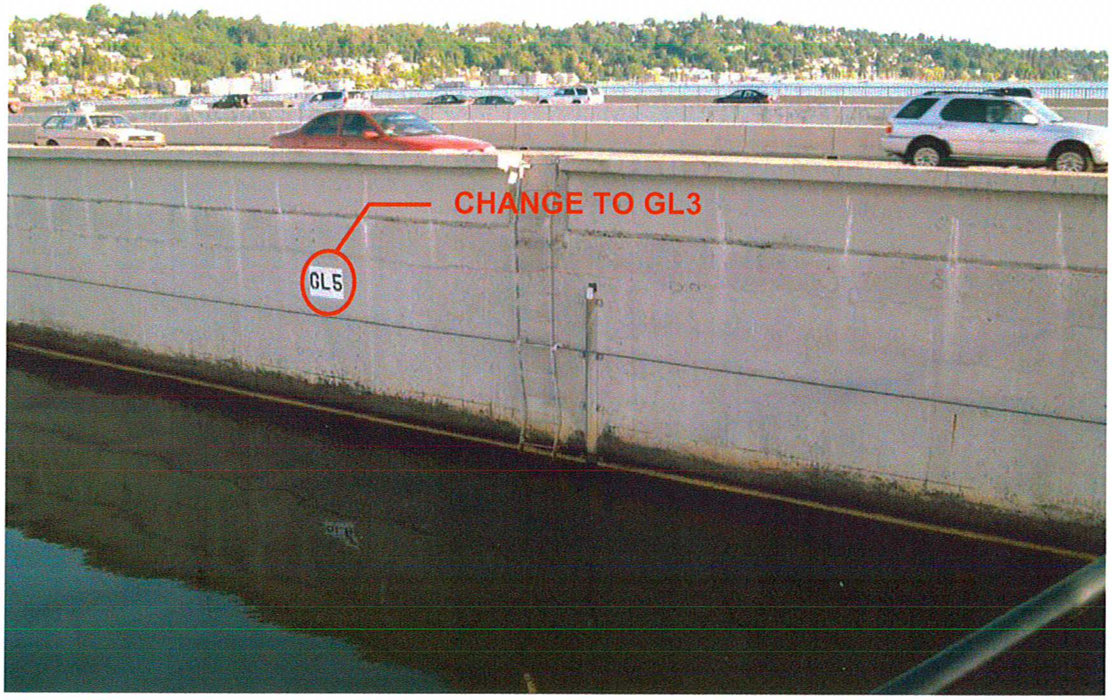
Figure A-6: Correction to Labels on Pontoons

LVM BRIDGE SOUTH SIDE PONTOON F

LVM BRIDGE SOUTH SIDE PONTOON F

Figure A-6: Correction to Labels on Pontoons (Continued)

LVM BRIDGE SOUTH SIDE PONTOON G



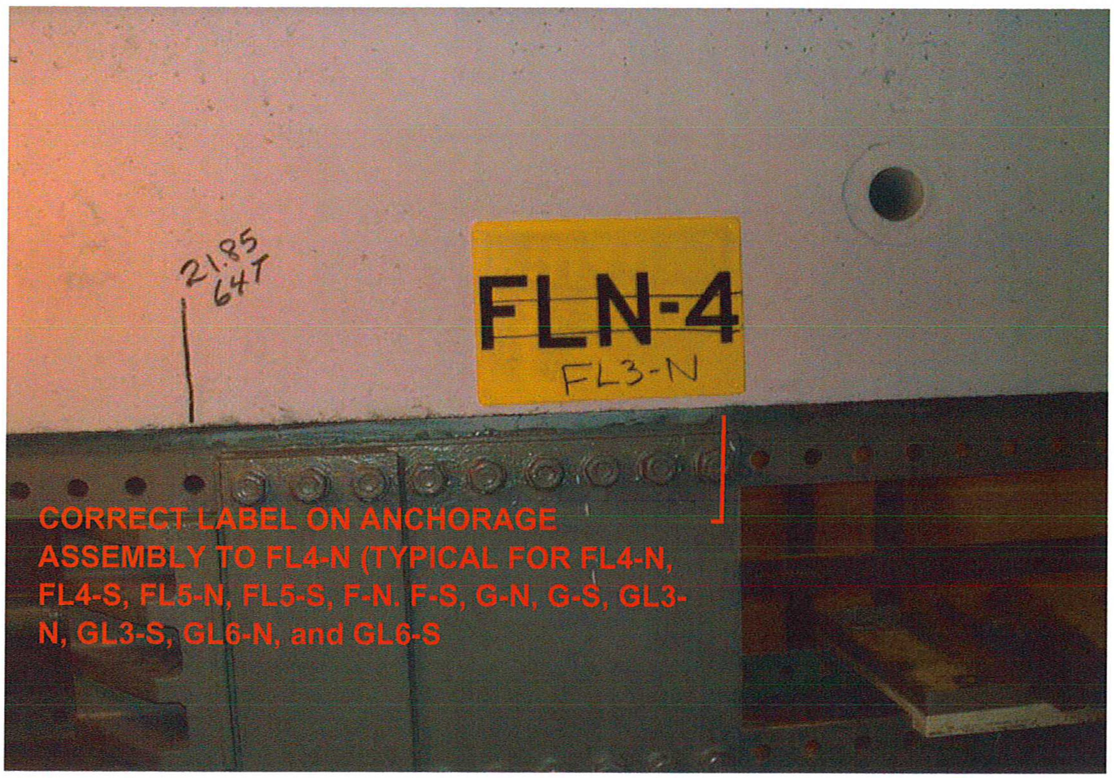


Figure A-6: Correction to Labels on Pontoons (Continued)

LVM BRIDGE NORTH SIDE PONTOON F

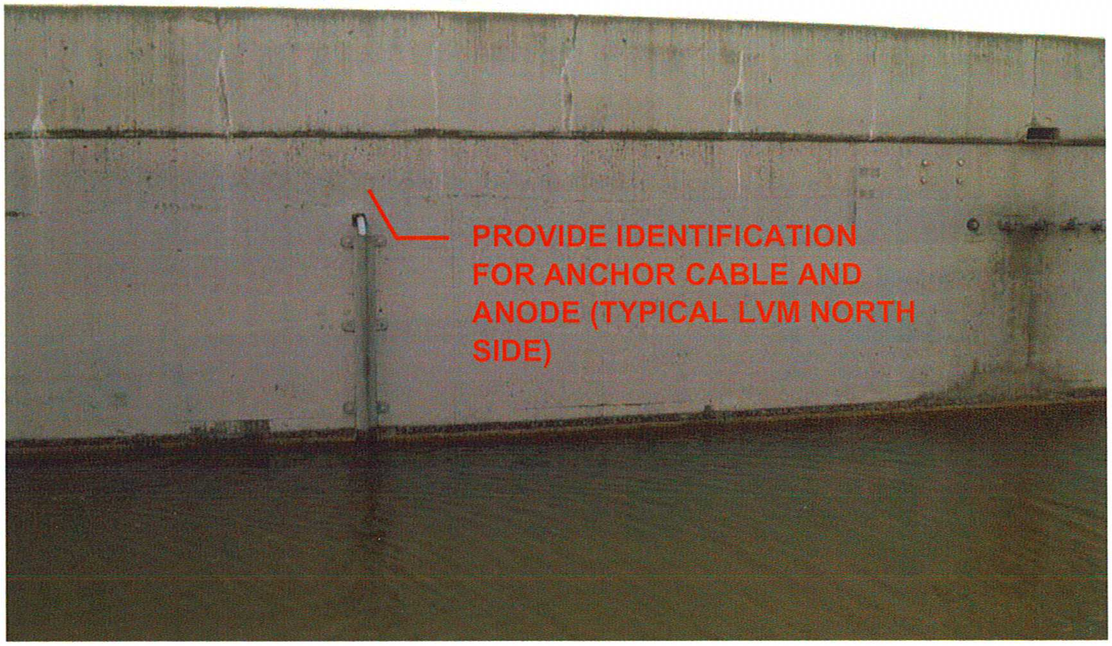
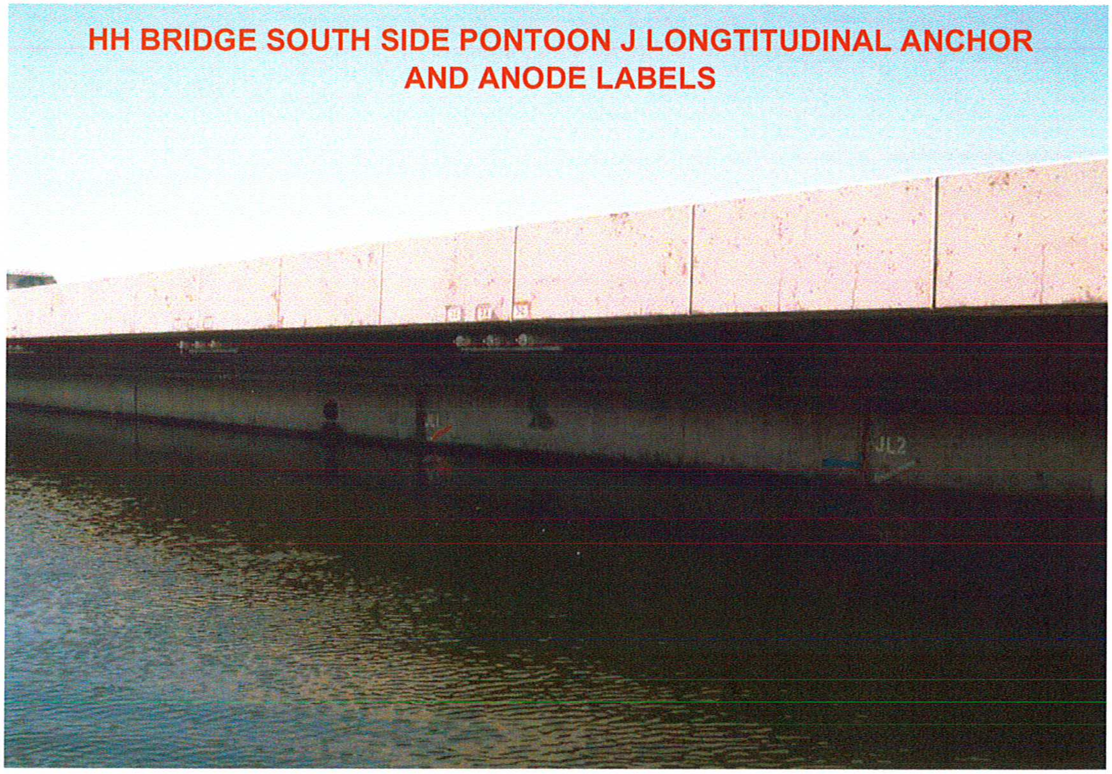


Figure A-6: Correction to Labels on Pontoons (Continued)



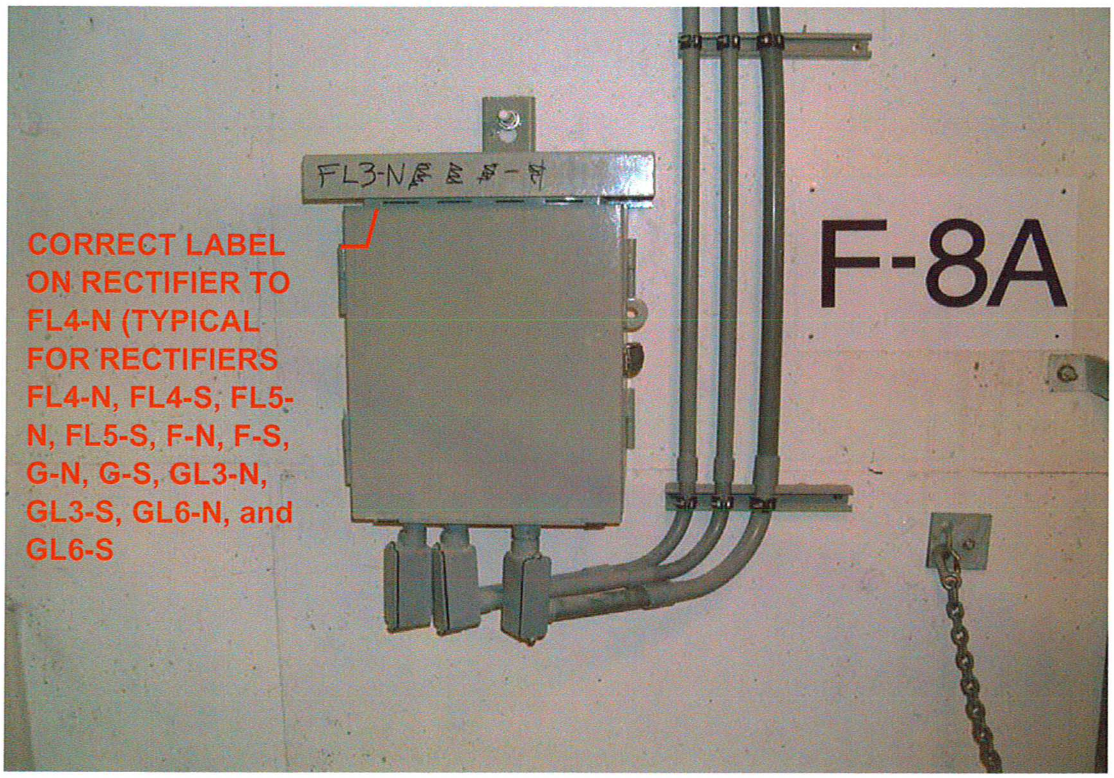


Figure A-7:Instant-Off Pontentials of Cable on the North Side of HH

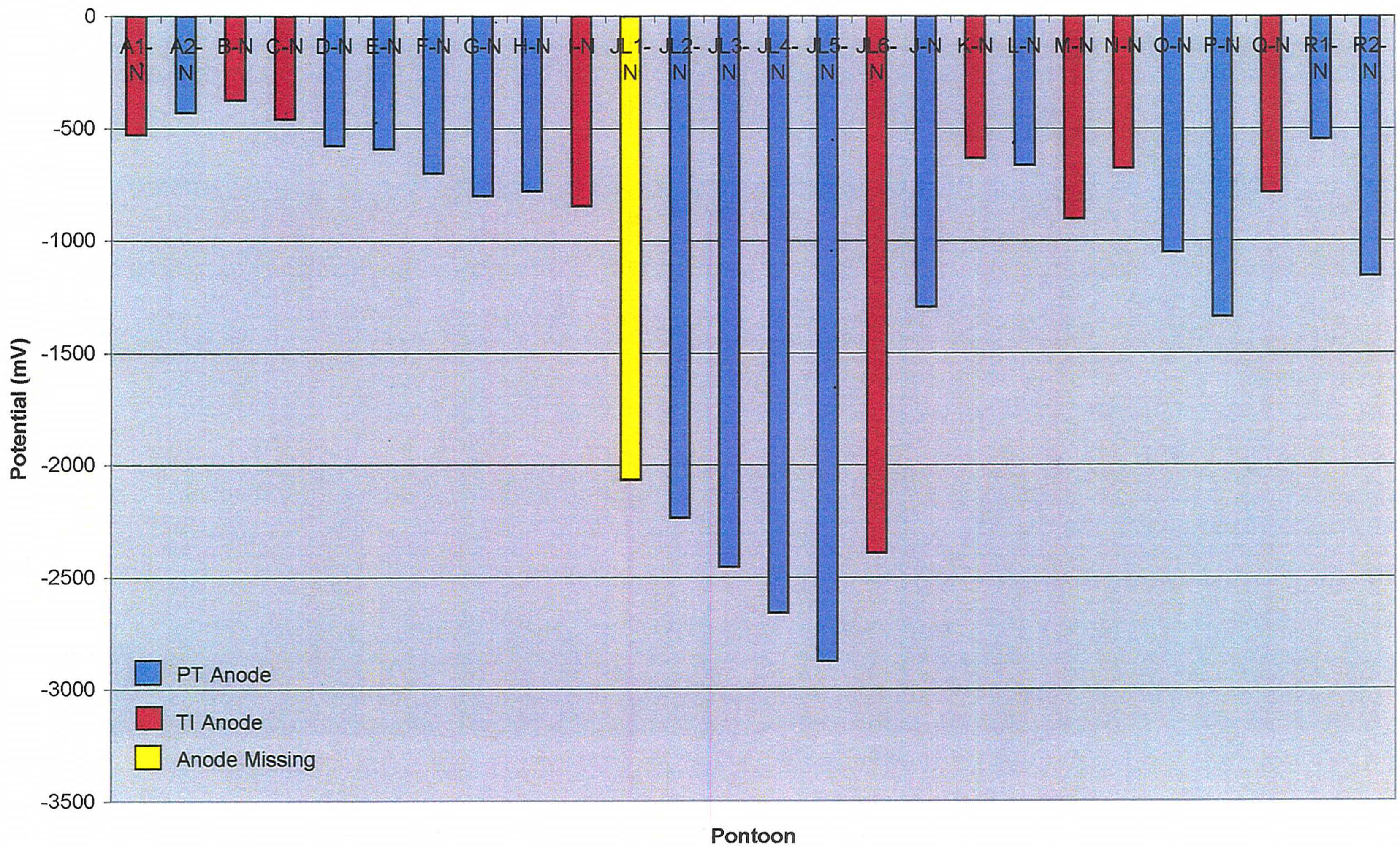


Figure A-8:Instant-off Potentials of Cable on the Southside of HH

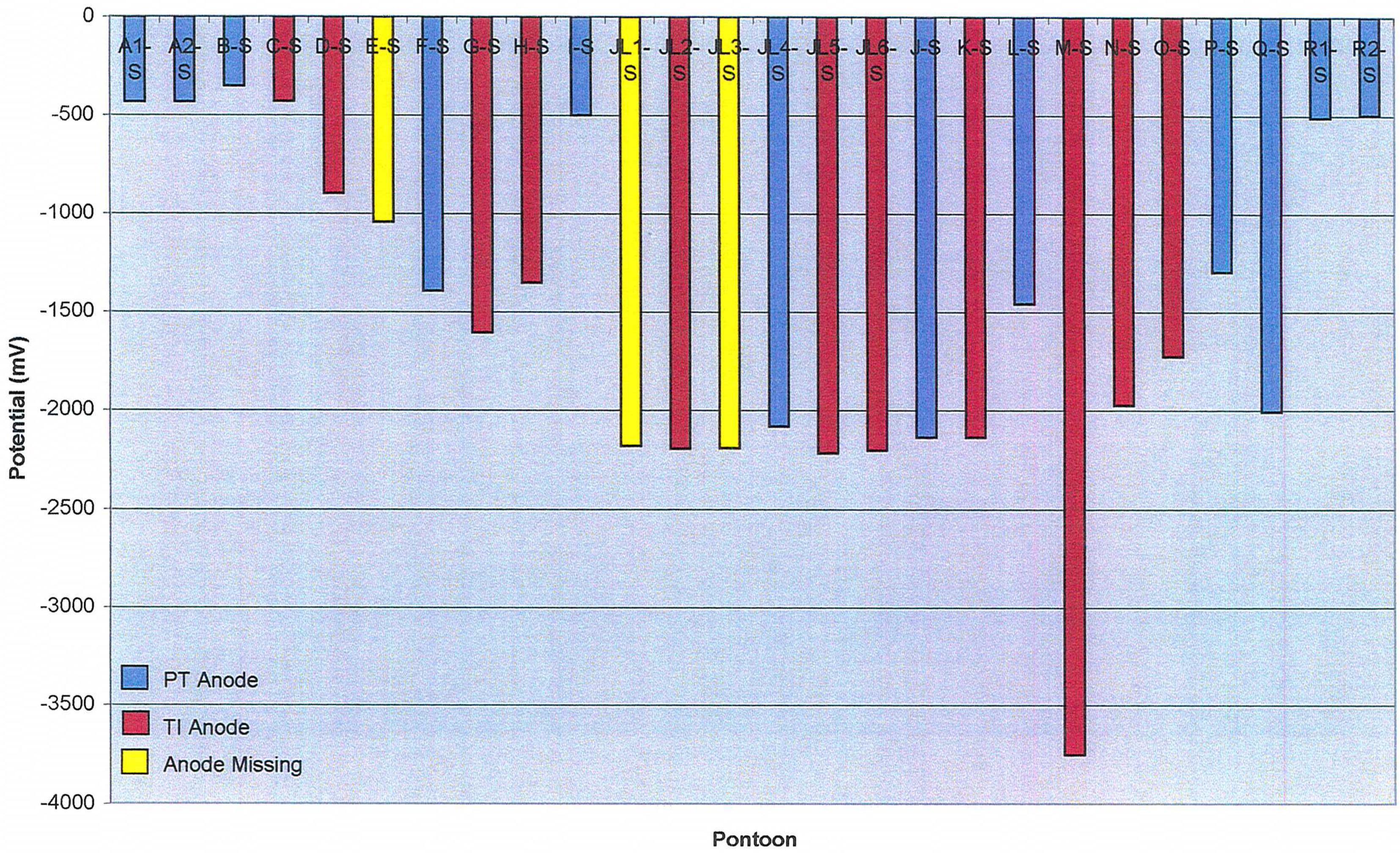


Figure A-9: Instant-off Potentials of Cables on the North Side of LVM

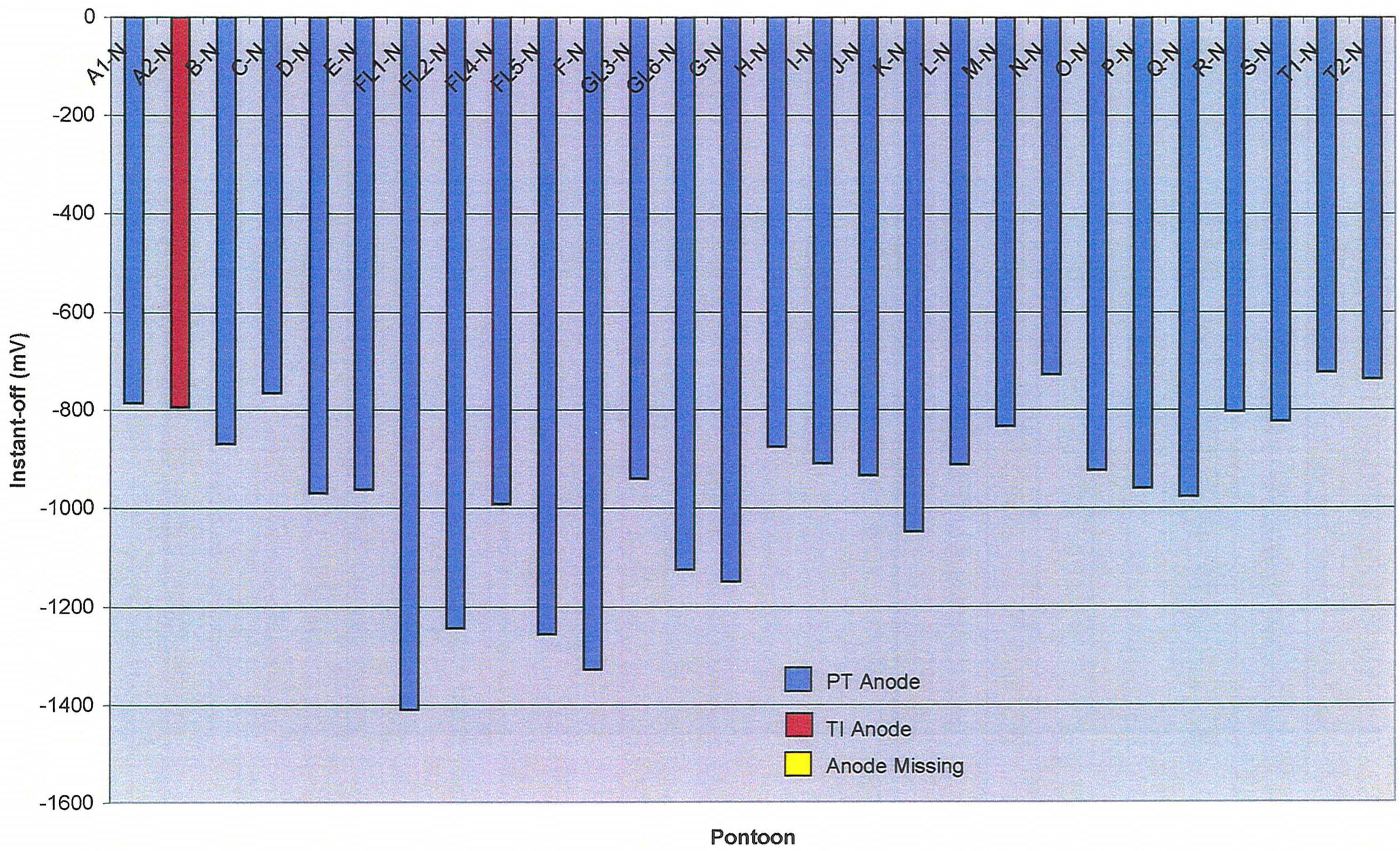
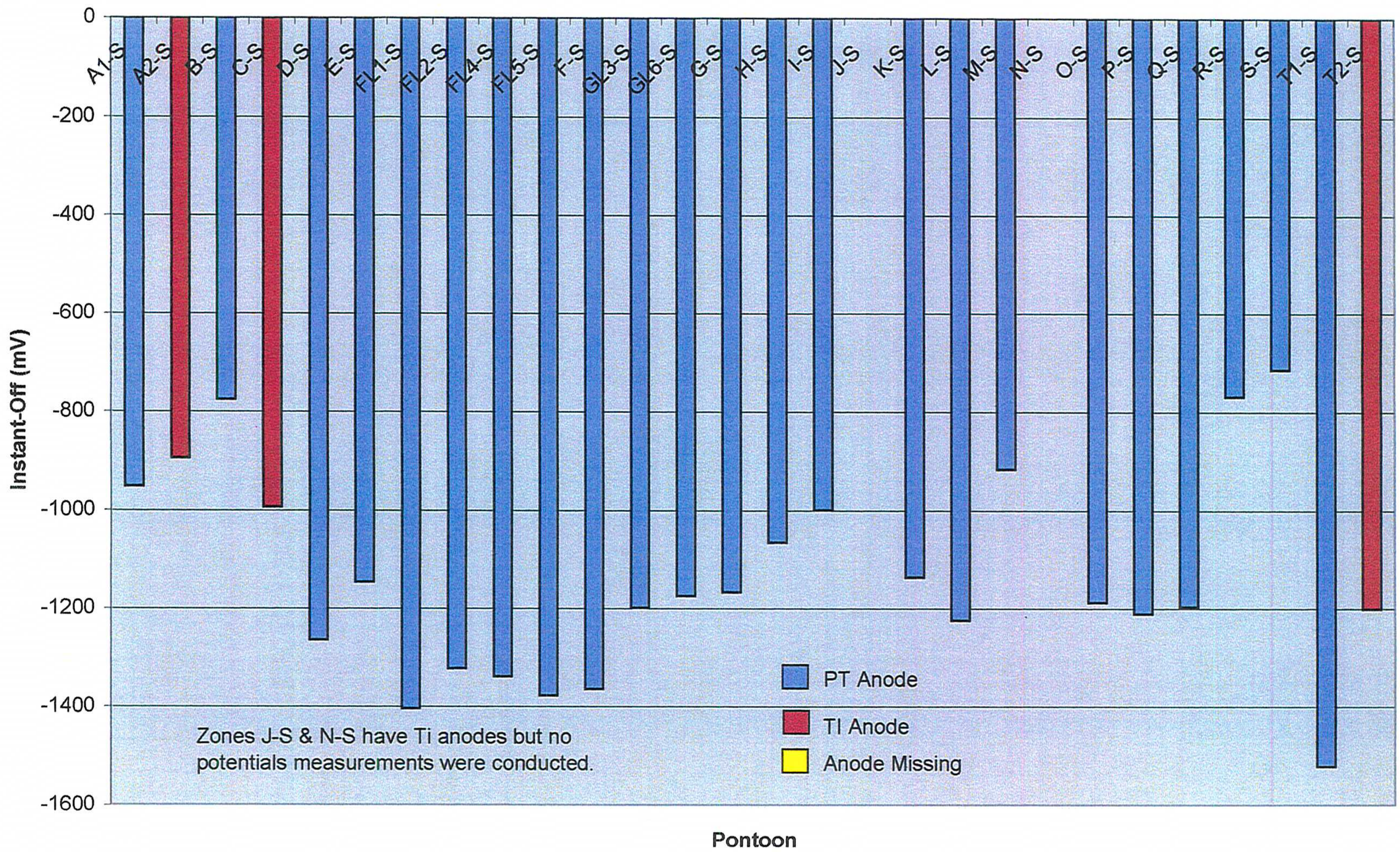


Figure A-10: Instant-off Potentials of Cables on the South Side of LVM



APPENDIX B

Table 1
Homer Hadley System Parameters

Pontoon	Output		IO Potential		Static mV	Resistance (Ω)	Depolarization mV	Polarization mV
	Voltage (V)	Current (A)	As-IS mV	ON mV				
A1-N	88.2	1.01		-531	-363			168
A2-N	28.07	2.02	-540	-431	-354	14	-186	77
B-N	94	1	-574	-375	-278	97	-296	97
C-N	92.5	1.04		-460	-369	91		91
D-N	21.2	2.12	-770	-578	-454	9.8	-316	124
E-N	20.54	2.1	-1015	-593	-394	9.4	-621	199
F-N	20.77	2.02	-985	-700	-533	9.6	-452	167
G-N	23.13	2.32	-730	-802	-515	96	-215	287
H-N	24.4	2.36	-759	-781	-482		-277	299
I-N			-763	-846	-807		44	39
JL1-N			-3960	-2068	-339		-3621	1729
JL2-N	34.26	3.18	-4200	-2235	-410	9.7	-3790	1825
JL3-N	32.92	2.76	-4100	-2455	-685	9.9	-3415	1770
JL4-N	39.21	3.4	-3820	-2659	-694	10	-3126	1965
JL5-N	36.34	3.26	-397	-2878	-750	10	353	2128
JL6-N	86.7	1.08	-3756	-2392	-357	84	-3399	2035
J-N	36.58	3.46	-1600	-1296	-329	9.6	-1271	967
K-N	91.9	1	-543	-632	-479	96	-64	153
L-N	21.24	2.08		-664	-517	9.5		147
M-N	92.4	0.96	-783	-903	-580	99	-203	323
N-N	82.5	0.9	-694	-678	-463	96	-231	215
O-N	40.9	2.01	-967	-1054			-967	1054
P-N	41.6	2.27	-1297	-1340	-653	17	-644	687
Q-N	88.5	0.93	-710	-784	-397	95	-313	387
R1-N	36.15	2.14	-848	-548	-504	17	-344	44
R2-N	39.4	2.13	-1358	-1158	-852	18	-506	306
A1-S	27.89	1.89	-657	-436	-347	14	-310	89
A2-S	28.95	1.99	-680	-435	-340	14	-340	95
B-S	20.1	2	-527	-354	-283	9.3	-244	71
C-S	92.8	1	-449	-431	-370	94	-79	61
D-S	90.8	1		-897	-437	96		460
E-S			-3329	-1043	-397		-2932	646
F-S	18.65	1.72	-3375	-1394	-496	9.5	-2879	898
G-S			-1918	-1607	-750		-1168	857
H-S	93.5	0.98	-1754	-1352	-360	96	-1394	992
I-S	32.4	3.4	-600	-502	-448	9.6	-152	54

Table 1
Homer Hadley System Parameters

Pontoon	Output		IO Potential		Static mV	Resistance (Ω)	Depolarization mV	Polarization mV
	Voltage (V)	Current (A)	As-IS mV	ON mV				
JL1-S			-4300	-2182			-4300	2182
JL2-S	89	0.94	-4300	-2195	-359	95	-3941	1836
JL3-S			-4280	-2191	-328		-3952	1863
JL4-S	32.82	3.1	-3220	-2080	-399	9.6	-2821	1681
JL5-S	91	1.02	-3450	-2217	-332	9.3	-3118	1885
JL6-S	91.5	1.02	-3459	-2204	-332	94	-3127	1872
J-S	29.66	2.8	-3076	-2136	-330	9.7	-2746	1806
K-S	92.5	1	-828	-2136	-481	97	-347	1655
L-S	20.13	2	-1603	-1458	-575	9.5	-1028	883
M-S	91.9	0.98	-1160	-3750	-366	97	-794	3384
N-S	88.8	0.98	-790	-1974	-470	96	-320	1504
O-S			-2180	-1730	-704		-1476	1026
P-S	35.09	2.04	-1875	-1297	-392	16	-1483	905
Q-S	42.4	2.6	-1217	-2008	-396	16	-821	1612
R1-S	41.2	2.42	-1965	-512	-464	17	-1501	48
R2-S	42.9	2.36	-1120	-499	-463	17	-657	36

Table 2
Lacey V. Murrow System Parameters

Pontoon	Output		IO Potential		Static	Resistance (Ω)	Depolarization mV	Polarization mV
	Voltage (V)	Current (A)	As-IS	ON				
A1-N	20.39	1.08	-770	-785	-473	20	297	312
A2-N	21.02	1.04	-759	-794	-474	17	285	320
B-N	16.6	0.86	-680	-869	-480	17	200	389
C-N	11.02	0.92	-818	-765	-520	9.4	298	245
D-N	14.29	1.29	-1140	-970	-712	9.5	428	258
E-N	12.82	1.04	-981	-963	-840	840	141	123
FL1-N	10.42	0.8	-1624	-1410	-766	9.4	858	644
FL2-N	12.6	0.94	-1185	-1245	-995	9.8	190	250
FL4-N	13.04	0.88	-1280	-992	-953	11	327	39
FL5-N	15.2	1.16	-1614	-1257	-949	10	665	308
F-N	12.5	0.9	-1573	-1328	-765	9.6	808	563
GL3-N	15.15	1.2	-459	-940	-975	10		
GL6-N	17.78	1.4	-1316	-1126	-1043	10	273	83
G-N	12.27	0.94	-1228	-1150	-782	9.6	446	368
H-N	13.31	1.16	-772	-876	-578	9.6	194	298
I-N	12.75	1.1	-930	-910	-624	9.5	306	286
J-N	12.57	0.98	-1109	-934	-875	10.3	234	59
K-N	12.9	1.06	-1016	-1048	-724	9.5	292	324
L-N	18.68	1.78	-830	-912	-598	9.4	232	314
M-N	10.9	0.9	-945	-834	-628	9.5	317	206
N-N	10.97	0.97	-697	-728	-590	9.3	107	138
O-N	20.64	1.1	-823	-924	-572	16	251	352
P-N	20.83	1.2	-803	-960	-590	17	213	370
Q-N	16.12	0.88	-942	-978	-568	16	374	410
R-N	24.74	1.4	-707	-804	-757	17		47
S-N	20.58	1.14	-805	-824	-425	16	380	399
T1-N	20.32	1.49	-1182	-723	-535	12	647	188
T2-N	13.89	1.02	-1097	-738	-535	9.8	562	203
A1-S	20.32	1.29	-721	-952	-5	12	716	947
A2-S	30.13	1.53	-685	-894	-7	17	678	887
B-S	25.15	1.41	-653	-775	-482	17	171	293
C-S	85.2	0.92	-930	-993	-519	3100	411	474
D-S	18.72	1.74	-1208	-1265	-710	9.7	498	555
E-S	18.35	1.71	-1070	-1147	-659	9.6	411	488
FL1-S	19.44	1.7	-1582	-1404	-768	10	814	636
FL2-S	17.82	1.38	-1535	-1323	-822	9.8	713	501

Table 2
Lacey V. Murrow System Parameters

Pontoon	Output		IO Potential		Static	Resistance (Ω)	Depolarization mV	Polarization mV
	Voltage (V)	Current (A)	As-IS	ON				
FL4-S	18.79	1.5	-1573	-1339	-768	10	805	571
FL5-S	21.53	1.9	-1671	-1378	-766	10	905	612
F-S	16.9	1.3	-1653	-1365	-765	9.8	888	600
GL3-S	13.8	1.06	-1228	-1199	-781	10	447	418
GL6-S	17.2	1.36	-1285	-1175	-817	10	468	358
G-S	17.22	1.52	-1281	-1167	-782	9.8	499	385
H-S	18.41	1.62	-936	-1065	-734	10	202	331
I-S	15.82	1.44		-999	-624	9.5		375
J-S	14.08	0.16			-1089			
K-S	17.07	1.56	-990	-1137	-721	9.6	269	416
L-S	15.26	1.42	-1131	-1225	-757	9.3	374	468
M-S	15.3	1.37	-1151	-916	-628	9.4	523	288
N-S			-808		-716		92	
O-S	15.69	1.39	-840	-1188	-568	10	272	620
P-S	20.75	1.72	-1057	-1212	-615	11	442	597
Q-S	24.44	1.36	-997	-1197	-567	16	430	630
R-S	21.49	1.1	-910	-769	-580	16	330	189
S-S	24.6	1.43	-706	-715	-423	17	283	292
T1-S	24.73	1.32	-1470	-1521	-740	17	730	781
T2-S	79.6	0.81	-640	-1202	-735			467

Table 3

Homer Hadley Bridge Summary

Pontoon	Anode Type	Target Current	Tap Setting	Action Required
A1-N	Ti	2.5	6-3	Extend existing anode to 3 anode string
A1-S	PT	2.5	2-2	
A2-N	PT	2.5	1-2	
A2-S	PT	2.5	1-2	
B-N	Ti	2.5	6-3	Extend existing anode to 3 anode string
B-S	PT	2.5	5-1	
C-N	Ti	2.5	6-3	Extend existing anode to 3 anode string
C-S	Ti	2.5	3-6	Extend existing anode to 3 anode string
D-N	PT	2.5	5-1	
D-S	Ti	2.5	6-3	Extend existing anode to 3 anode string
E-N	PT	2.5	5-1	
E-S		2.5		Install 3 Anode String
F-N	PT	2.5	5-1	
F-S	PT	2.5	5-1	
G-N	PT	2.5	6-1	
G-S	Ti	2.5		Extend existing anode to 3 anode string
H-N	PT	2.5	1-2	
H-S	Ti	2.5	6-3	Extend existing anode to 3 anode string
I-N	Ti	2.5		Extend existing anode to 3 anode string
I-S	PT	2.5	2-2	
J-N	PT	2.5	3-2	
J-S	PT	2.5	2-2	
JL1-N		2.5		Install 3 Anode String
JL1-S		2.5		Install 3 Anode String
JL2-N	PT	2.5	2-2	
JL2-S	Ti	2.5	6-3	Extend existing anode to 3 anode string
JL3-N	PT	2.5	3-2	
JL3-S		2.5		Install 3 Anode String

Table 3
Homer Hadley Bridge Summary

Pontoon	Anode Type	Target Current	Tap Setting	Action Required
JL4-N	PT	2.5	4-2	
JL4-S	PT	2.5	3-2	
JL5-N	PT	2.5	3-2	
JL5-S	Ti	2.5	6-3	Extend existing anode to 3 anode string
JL6-N	Ti	2.5	6-3	Extend existing anode to 3 anode string
JL6-S	Ti	2.5	6-3	Extend existing anode to 3 anode string
K-N	Ti	2.5	6-3	Extend existing anode to 3 anode string
K-S	Ti	2.5	6-3	Extend existing anode to 3 anode string
L-N	PT	2.5	6-1	
L-S	PT	2.5	5-1	
M-N	Ti	2.5	6-3	Extend existing anode to 3 anode string
M-S	Ti	2.5	6-3	Extend existing anode to 3 anode string
N-N	Ti	2.5	6-3	Extend existing anode to 3 anode string
N-S	Ti	2.5	6-3	Extend existing anode to 3 anode string
O-N	PT	2.5	4-2	
O-S	Ti	2.5		Extend existing anode to 3 anode string
P-N	PT	2.5	4-2	
P-S	PT	2.5	3-2	
Q-N	Ti	2.5	6-3	Extend existing anode to 3 anode string
Q-S	PT	2.5	4-2	
R1-N	PT	2.5	3-2	
R1-S	PT	2.5	4-2	
R2-N	PT	2.5	3-2	
R2-S	PT	2.5	4-2	

Table 4
Lacey V. Murrow Bridge Summary

Pontoon	Anode Type	Target Current	Tap Setting	Action Required
A1-N	PT	1.00	1-6	
A1-S	PT	1.50	1-5	
A2-N	PT	1.00	1-4	Remove existing PT and extend the existing Ti to 3 anode string
A2-S	TI	1.50	2-1	Remove existing PT and extend the existing Ti to 3 anode string
B-N	PT	1.00	1-4	
B-S	PT	1.50	1-6	
C-N	PT	1.00	1-3	
C-S	TI	1.50	3-5	Extend existing Ti to 3 anode string
D-N	PT	1.00	1-4	
D-S	PT	1.50	1-4	
E-N	PT	1.00	1-3	
E-S	PT	1.50	1-4	
FL1-N	PT	1.00	A-3	
FL1-S	PT	1.50	A-4	
FL2-N	PT	1.00	1-3	
FL2-S	PT	1.50	1-4	
FL4-N	PT	1.00	A-4	
FL4-S	PT	1.50	A-5	
FL5-N	PT	1.00	1-4	
FL5-S	PT	1.50	B-1	
F-N	PT	1.00	1-3	
F-S	PT	1.50	1-4	
GL3-N	PT	1.00	A-4	
GL3-S	PT	1.50	A-4	
GL6-N	PT	1.00	1-4	
GL6-S	PT	1.50	1-4	
G-N	PT	1.00	1-3	
G-S	PT	1.50	1-4	
H-N	PT	1.00	1-3	
H-S	PT	1.50	1-4	

Table 4

Lacey V. Murrow Bridge Summary

Pontoon	Anode Type	Target Current	Tap Setting	Action Required
I-N	PT	1.00	1-3	
I-S	PT	1.50	1-4	
J-N	PT	1.00	1-3	
J-S	Ti	1.50		Extend existing Ti to 3 anode string
K-N	PT	1.00	1-3	
K-S	PT	1.50	1-4	
L-N	PT	1.00	2-3	
L-S	PT	1.50	1-4	
M-N	PT	1.00	1-3	
M-S	PT	1.50	1-4	
N-N	PT	1.00	1-3	
N-S	TI	1.50		Extend existing Ti to 3 anode string
O-N	PT	1.00	1-5	
O-S	PT	1.50	1-4	
P-N	PT	1.00	1-5	
P-S	PT	1.50	1-5	
Q-N	PT	1.00	1-4	
Q-S	PT	1.50	1-5	
R-N	PT	1.00	1-5	
R-S	PT	1.50	1-6	
S-N	PT	1.00	1-5	
S-S	PT	1.50	1-6	
T1-N	PT	1.00	1-4	Install 3 Anode String for failed anode. Disconnect other PT
T1-S	PT	1.50	1-5	
T2-N	PT	1.00	1-4	
T2-S	TI	1.50	3-4	Extend existing Ti to 3 anode string

APPENDIX C

HOMER HADLEY BRIDGE (I-90)
CATHODIC PROTECTION DATA

A1-N

RECTIFIER INFORMATION

Manufacturer: UNIVERSAL RECTIFIERS
Rectifier Type: SILICON STACK
Input Voltage: 120 Filtered: NO
Volts (Rated): 80 Amps (Rated): 8
Shunt: 50/5 (mV/10=A)

ZONE INFORMATION

Anode Type: Ti Anode Length:
Number of Anodes: 1

TARGET CURRENT	TAP SETTING	
	COARSE	FINE
2.5	3	6

DATE	TIME	DATA TYPE	RECTIFIER		FLUKE 87		ANODE IO (mV)	CABLE IO (mV)	AC Ω	COMMENTS
			VOLTS	AMPS	VOLTS	AMPS				
5/3/2004	07:34	AS IS	57.0	4.5	55.40	4.46	3600	-532		1/2" PT BURN
5/11/2004		STATIC					-188	-488		
5/17/2004		ON			54.70	4.20	3600	-1008		
3/8/2006	10:05	AS IS	69.0	0.0	67.60	0.00	-444	-5950		ANODE MISSING
3/8/2006		STATIC						-363		TAP 3-1
3/20/2006	08:28	ON						-450		POWER OFF - INSTALLED NEW ANODE 3/22
3/22/2006	08:52	ENER	92.0	0.9	88.20	0.98	1040	-820		TAP 3-6
3/23/2006	07:57	ON	90.0	1.0	88.20	1.01	1674	-531		

NOTES:

HOMER HADLEY BRIDGE (I-90)

CATHODIC PROTECTION DATA

A1-S

RECTIFIER INFORMATION

Manufacturer: UNIVERSAL RECTIFIERS

Rectifier Type: SILICON STACK

Input Voltage: 120 Filtered: NO

Volts (Rated): 80 Amps (Rated): 8

Shunt: 50/5 (mV/10=A)

ZONE INFORMATION

Anode Type: PT Anode Length: 54'

Number of Anodes: 1

TARGET CURRENT	TAP SETTING	
	COARSE	FINE
2.5	2	2

DATE	TIME	DATA TYPE	RECTIFIER		FLUKE 87		ANODE IO (mV)	CABLE IO (mV)	AC Ω	COMMENTS
			VOLTS	AMPS	VOLTS	AMPS				
5/3/2004	07:43	AS IS	54.0	3.5	52.70	4.20	3600	-1124		1/2" PT BURN - TOP & BOTTOM
5/11/2004		STATIC					-230	-937		
5/17/2004		ON			51.50	3.96	4800	-536		
3/8/2006	10:15	AS IS	54.0	4.0	52.80	3.76	3211	-657		2" TOP / 1/2" BOTTOM PT BURN
3/15/2006	01:10	STATIC					354	-347	14.0	TAP 3-1
						1.95				TAP 2-1
3/20/2006	08:21	ON	28.0	2.0	27.89	1.89	2826	-436		
						2.17				READJUSTED TO TAP 2-2

NOTES:

HOMER HADLEY BRIDGE (I-90)
CATHODIC PROTECTION DATA

A2-N

RECTIFIER INFORMATION

Manufacturer: UNIVERSAL RECTIFIERS
Rectifier Type: SILICON STACK
Input Voltage: 120 Filtered: NO
Volts (Rated): 80 Amps (Rated): 8
Shunt: 50/5 (mV/10=A)

ZONE INFORMATION

Anode Type: PT Anode Length: 48'
Number of Anodes: 1

TARGET CURRENT	TAP SETTING	
	COARSE	FINE
2.5	2	1

DATE	TIME	DATA TYPE	RECTIFIER		FLUKE 87		ANODE IO (mV)	CABLE IO (mV)	AC Ω	COMMENTS
			VOLTS	AMPS	VOLTS	AMPS				
5/3/2004	07:26	AS IS	48.0	3.7	47.00	3.60	2400	-1000		1/2" PT BURN - TOP & BOTTOM
5/11/2004		STATIC					156	-490		
5/17/2004		ON			46.60	3.53	3600	-1020		
3/8/2006	10:10	AS IS	48.0	3.6	46.50	3.43	1685	-540		PT BURN - 1 7/8" TOP / 1/2" BOTTOM
3/15/2006	01:17	STATIC					257	-354	14.0	TAP 2-5
						2.04				TAP 2-1
3/20/2006	03:31	ON	29.0	2.2	28.07	2.02	1638	-431		

NOTES:

HOMER HADLEY BRIDGE (I-90)

CATHODIC PROTECTION DATA

A2-S

RECTIFIER INFORMATION

Manufacturer: UNIVERSAL RECTIFIERS

Rectifier Type: SILICON STACK

Input Voltage: 120 Filtered: NO

Volts (Rated): 80 Amps (Rated): 8

Shunt: 50/5 (mV/10=A)

ZONE INFORMATION

Anode Type: PT Anode Length: 61'

Number of Anodes: 1

TARGET CURRENT	TAP SETTING	
	COARSE	FINE
2.5	2	1

DATE	TIME	DATA TYPE	RECTIFIER		FLUKE 87		ANODE IO (mV)	CABLE IO (mV)	AC Ω	COMMENTS
			VOLTS	AMPS	VOLTS	AMPS				
5/3/2004	07:39	AS IS	56.0	4.3	54.50	4.29	2800	-1132		PT BURN - 2" TOP / 1/4" BOTTOM
5/11/2004		STATIC					-255	-928		
5/17/2004		ON			53.90	4.19	4400	-536		
3/8/2006	10:20	AS IS	56.0	4.2	54.80	3.96	3070	-680		PT BURN - 2 1/8" TOP / 1/4" BOTTOM
3/15/2006	01:07	STATIC					310	-340	14.0	TAP 3-1
						2.03				TAP 2-1
3/20/2006	08:15	ON	30.0	2.1	28.95	1.99	2500	-435		

NOTES:

HOMER HADLEY BRIDGE (I-90)
CATHODIC PROTECTION DATA

B-N

RECTIFIER INFORMATION

Manufacturer: UNIVERSAL RECTIFIERS
Rectifier Type: SILICON STACK
Input Voltage: 120   Filtered: NO
Volts (Rated): 80   Amps (Rated): 8
Shunt: 50/10 (2*mV/10=A)

ZONE INFORMATION

Anode Type: TI   Anode Length: ____
Number of Anodes: 1

TARGET CURRENT	TAP SETTING	
	COARSE	FINE
2.5	3	6

DATE	TIME	DATA TYPE	RECTIFIER		FLUKE 87		ANODE IO (mV)	CABLE IO (mV)	AC Ω	COMMENTS
			VOLTS	AMPS	VOLTS	AMPS				
5/3/2004	08:15	AS IS								SYSTEM OFF
5/11/2004		STATIC								ANODE MISSING
5/17/2004		ON								SYSTEM OFF
3/8/2006	10:31	AS IS	44.0	0.4	45.10	0.46	1067	-574		NEW ANODE - Cu CORRODING
3/15/2006	01:00	STATIC					12	-278	97.0	TAP 2-3
						1.00				TAP 3-6
3/20/2006	08:41	ON	94.0	1.0	94.00	1.00	1352	-375		

NOTES:

HOMER HADLEY BRIDGE (I-90)
CATHODIC PROTECTION DATA

B-S

RECTIFIER INFORMATION

Manufacturer: UNIVERSAL RECTIFIERS
Rectifier Type: SILICON STACK
Input Voltage: 120 Filtered: NO
Volts (Rated): 80 Amps (Rated): 8
Shunt: 50/10 (2*mV/10=A)

ZONE INFORMATION

Anode Type: PT Anode Length: 73'
Number of Anodes: 1

TARGET CURRENT	TAP SETTING	
	COARSE	FINE
2.5	1	5

DATE	TIME	DATA TYPE	RECTIFIER		FLUKE 87		ANODE IO (mV)	CABLE IO (mV)	AC Ω	COMMENTS
			VOLTS	AMPS	VOLTS	AMPS				
5/3/2004	08:06	AS IS	44.0	4.8	43.60	4.90	2400	-936		PT BURN - 4" TOP / 1" BOTTOM
5/11/2004		STATIC					-210	-551		
5/17/2004		ON			43.30	4.90	4000	-652		
3/8/2006	10:26	AS IS	42.0	4.6	42.70	4.50	1578	-527		PT BURN - 4" TOP / 1" BOTTOM
3/15/2006	12:57	STATIC					195	-283	9.3	TAP 2-4
						2.11				TAP 1-5
3/20/2006	08:38	ON	20.0	2.0	20.10	2.00	1673	-354		

NOTES:

HOMER HADLEY BRIDGE (I-90)

CATHODIC PROTECTION DATA

C-N

RECTIFIER INFORMATION

Manufacturer: UNIVERSAL RECTIFIERS

Rectifier Type: SILICON STACK

Input Voltage: 120 Filtered: NO

Volts (Rated): 80 Amps (Rated): 8

Shunt: 50/10 (2*mV/10=A)

ZONE INFORMATION

Anode Type: Ti Anode Length:

Number of Anodes: 1

TARGET CURRENT	TAP SETTING	
	COARSE	FINE
2.5	3	6

DATE	TIME	DATA TYPE	RECTIFIER		FLUKE 87		ANODE IO (mV)	CABLE IO (mV)	AC Ω	COMMENTS
			VOLTS	AMPS	VOLTS	AMPS				
5/3/2004	08:31	AS IS	50.0	5.4	49.20	5.40	2800	-1036		ANODE FAILED DURING INSPECTION
5/11/2004		STATIC					760	-430		ANODE REMOVED
5/17/2004		ON								SYSTEM OFF
3/8/2006	10:38	AS IS	66.0	0.0						BLOWN FUSE - REPLACED & ENERGIZED
3/9/2006	07:32		61.0	0.8	60.20	0.68	1215	-468		NEW ANODE
3/15/2006	12:38	STATIC					124	-369	91.0	TAP 2-6
						1.04				TAP 3-6
3/20/2006	08:49	ON	94.0	1.0	92.50	1.04	1325	-460		

NOTES:

HOMER HADLEY BRIDGE (I-90)
CATHODIC PROTECTION DATA

C-S

RECTIFIER INFORMATION

Manufacturer: UNIVERSAL RECTIFIERS
Rectifier Type: SILICON STACK
Input Voltage: 120 Filtered: NO
Volts (Rated): 80 Amps (Rated): 8
Shunt: 50/10 (2*mV/10=A)

ZONE INFORMATION

Anode Type: Ti Anode Length:
Number of Anodes: 1

TARGET CURRENT	TAP SETTING	
	COARSE	FINE
2.5	3	6

DATE	TIME	DATA TYPE	RECTIFIER		FLUKE 87		ANODE IO (mV)	CABLE IO (mV)	AC Ω	COMMENTS
			VOLTS	AMPS	VOLTS	AMPS				
5/3/2004	08:28	AS IS	56.0	0.0	55.90	0.00	55500	-433		ANODE MISSING
5/11/2004		STATIC					-410	-430		
5/17/2004		ON								SYSTEM OFF
3/8/2006	10:42	AS IS	46.0	0.4	44.70	0.46	1079	-449		NEW ANODE
3/8/2006		STATIC					24	-370	94.0	TAP 2-3
						1.00				TAP 3-6
3/20/2006	08:53	ON	96.0	1.0	92.80	1.00	1309	-431		

NOTES: